STORAGE AND SHELF LIFE of PACKAGED GREEN ONIONS

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UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

U.S. Department of Agriculture marketing research is part of a continuing program to reduce marketing losses and to extend the marketing season of agricultural products. This study was undertaken to find improved methods for the handling, storage, and packaging of fresh green onions.

R. E. Hardenburg made suggestions in planning the experiments; R. H. Day set up and maintained the controlled-atmosphere chambers; W. J. Lipton supplied background information on western-grown green onions; and E. James Koch advised on experimental design and data analysis. All are employees of the Agricultural Research Service.

Norman J. Smith, Extension Service, U.S. Department of Agriculture, and Lou Galetto and family, produce growers, Vineland, N.J., harvested and assisted in packing the green onions for some storage experiments.

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STORAGE AND SHELF LIFE of PACKAGED GREEN ONIONS

By HOWARD W. HRUSCHKA, *research plant physiologist, Horticultural Crops Marketing Laboratory, Northeastern Region, Agricultural Research Service*

SUMMARY

Storage and shelf-life tests were made using about 2,400 bunches of Beltsville Bunching and White Knight green onions. They were sent to Beltsville, Md., from New Jersey, Arizona, and Mexico under top and package ice in wirebound wood crates and waxed corrugated cardboard cartons.

From a reported fresh life of a few days at 32° F, the storage and shelf life of fresh green onions was extended to 4 weeks by holding the onions in air storage at 32° with or without top ice and after consumer packaging to 10 additional days at 32° or 1 additional day at 70°. Under film-wrap protection and in controlled atmospheres of 1 percent oxygen with 5 percent carbon dioxide or of 100 percent nitrogen, storage life was further extended to 8 weeks at 32° plus 1-day shelf life at 70°. After 10 or 12 weeks' storage in cartons at 32° in controlled atmospheres and with subsequent trimming and consumer packaging, green onions had remaining a shelf life of 3 days at 32° or 1 day at 70°.

Also presented are data on respiration, heat-evolution rates, and leaf elongation with accompanying geotropic curvature.

BACKGROUND

Names in common usage for green onions (*Allium cepa* L., *A. fistulosum* L., and their crosses) include onions, spring onions, green onions, green bunching onions, bunch onions, bunching onions, Welsh bunching onions, Japanese bunching onions, scallions, eschalots, and shallots (*8*, *14*).[1]

Annual worldwide consumption of green onions and of mature bulb onions is about 7½ million metric tons (2,200 lb per ton) each (*8*). The United States leads the world in mature onion production at 1.4 million metric tons per year and also produces about 0.2 million metric ton of green onions per year. Because of widespread plantings and excellent refrigerated transport, fresh green onions are available at U.S. markets throughout the year.

Some defects, diseases, and insects that affect mature bulb onions during the growing season can also affect green onions (*8*, *12*, *13*, *15*). However, little or no information is available on these afflications of green onions in transit or during marketing except concerning gray mold (*Botrytis allii*), which was reported to cause rot lesions in green onions in some rail shipments from Arizona to Chicago and Milwaukee (*1*).

Optimum storage conditions for freshly harvested green onions were reported as 32° F and 90 to 95 percent relative humidity (*10*). Holding at 32° to prevent yellowing and decay and the use of crushed ice to maintain freshness were recommended for green onions in retail stores (*9*). The highest freezing point of green onions was listed as 30.4° (*16*). Tests with leeks (*2*) and with

[1] Italic numbers in parentheses refer to Literature Cited, p. 21.

daffodils (*11*) suggested that modifying storage atmospheres with carbon dioxide or nitrogen or packaging in nonperforated plastic bags may delay the yellowing and rotting of leaves.

The purpose of this study was to find improved methods for the handling, storage, and packaging of fresh green onions. Reports of similar research on other commodities are available (*3, 4, 5, 7, 10*).

METHODS AND MATERIALS

At Beltsville, Md., from August 1969 to August 1970, tests were conducted using about 2,400 bunches of green onions, including mainly crates of Beltsville Bunching variety onions (*A. cepa* × *A. fistulosum*) grown in New Jersey and waxed cartons of White Knight variety onions (*A. cepa*) grown in Arizona and Mexico (figs. 1 and 2) (*17*). These shipping and storage crates were of wire-bound wood construction, measuring 20 by 11 by 7½ inches inside and 22 by 11½ by 8 inches outside. The cartons were water-resistant, waxed-corrugated cardboard, measuring 15¼ by 10 by 11¼ inches inside and 15¾ by 10½ by 11¾ inches outside. In Arizona and Mexico, onions are pulled by hand, trimmed with a knife to about 15-inch length in a trim box, gathered as one handful of 6 to 10 onions per bunch, and secured with a twist tie or rubberband. Six hand bunches are grouped with a longer twist tie into a master bunch. Then eight master bunches are packed in a waxed carton (fig. 1) for transportation to market. Some Mexican and western onions are packed as 48 separate bunches in a waxed carton. The bunches of green onions are nonwrapped within the carton

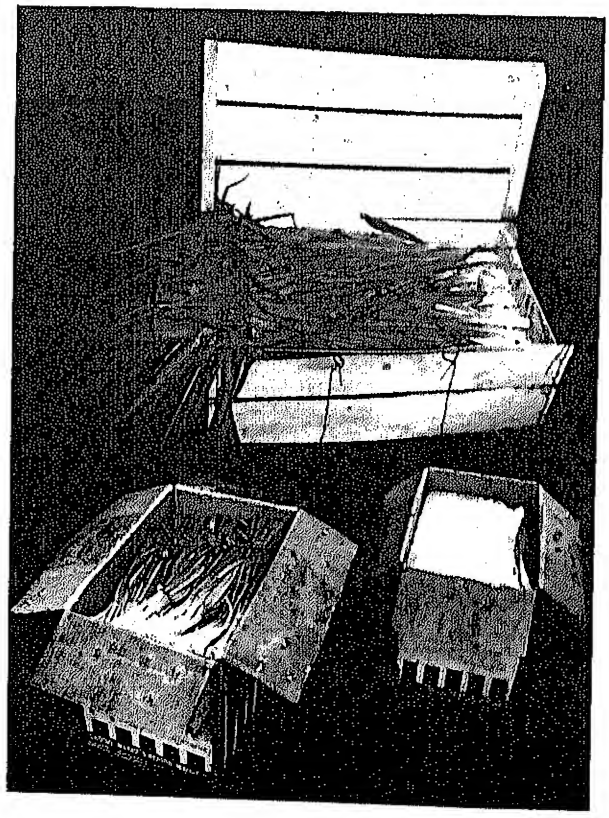

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FIGURE 1.—Wirebound wood crate and waxed cartons for shipping and storing green onions. Package ice over parchment in carton (*right*) and master bunches of onions after ice and parchment are removed from carton (*left*).

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FIGURE 2.—Harvesting green onions by hand in Phoenix, Ariz., area.

During storage or holding tests, crates were nonlined or fitted with a 1.5-mil polyethylene film liner perforated with fifty-two $\frac{1}{16}$-inch holes. Bunches were each secured by two rubberbands and either nonwrapped or wrapped in a perforated (sixteen $\frac{1}{16}$-inch holes) polyethylene (1.5 mil) bag with rubberband closure or in a sleeve of heat-shrinkable polyvinyl chloride film perforated with $\frac{1}{64}$-inch holes spaced one-half inch apart (fig. 3). In some tests, nonperforated polyethylene bags were tied to be airtight. Other details on methods and materials are given under individual tests.

Generally tests were set up in split-plot experimental design. Where appropriate, the data were processed by analysis of variance and Duncan's multiple-range test at the 5-percent level of statistical significance (*6*).

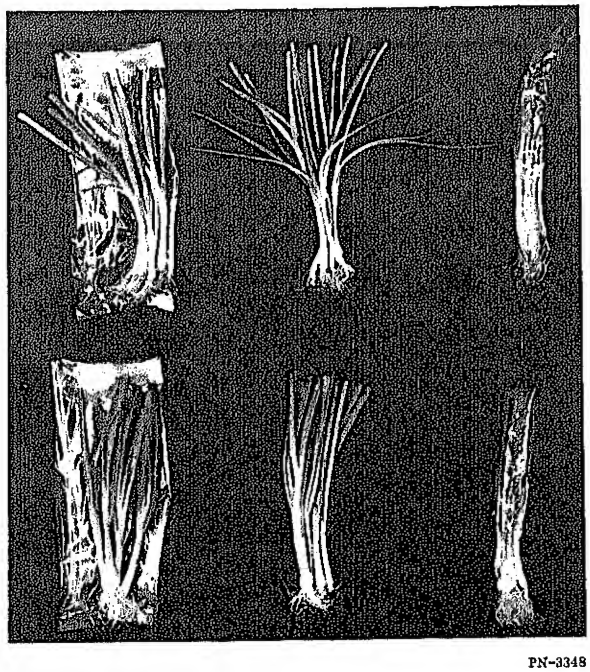

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FIGURE 3.—Packaging of trimmed green onions in holding tests for 1 day at 70° F (*above*) and 32° (*bel* plete polyethylene overwrap; *center*, no wrap; *right*, polyvinyl sleeve overwrap. Onions at 32° (*bel* green, and free of growth and curvature, whereas onions at 70° (*above*) show moderate to severe curva growth beyond end of sleeve wrap (*right*).

PRELIMINARY TESTS AND OBSERVATIONS

Store Survey

Bunches of green onions bought at 10 supermarkets near the Beltsville laboratory weighed from 70 to 221 grams. The retail cost was from 3 to 19.5 cents per bunch or from 3 to 20 cents per 100 grams. The edible portion cost 4 to 33 cents per 100 grams. Appearance ratings of green onions in the stores were as follows:

Ratings	*Stores*
Excellent	2
Excellent and good	1
Fair and poor	3
Poor	3
Very poor	1

Onions rated excellent and good were considered fully salable; fair, barely salable; and poor or very poor, not salable.

Excellent or good onions were slightly better after they were trimmed of about 6-percent weight. Fair, poor, and very poor onions required 21-, 26-, and 36-percent trim, respectively (fig. 4). After trimming, all onions were rated fresh and green, good to excellent; all were fully salable.

Elongation During Preliminary Holding Tests

Onions initially trimmed to 8-inch length elongated only 2.2 to 4.8 percent when held 4 days at 32° or 40° F, respectively (table 1). Elongation was faster in onions held at higher temperatures and averaged 53.5-percent increase when held 4 days at 70°. The green onions remained upright in the holding crocks and showed no geotropic curvature during elongation. In other observations when elongation occurred after green onions were placed horizontally, severe curvature eventually resulted (fig. 5). Onions remained salable after 4 days at 32° or 40°, but they were unsalable after 3 days at 50° or 60° or after 2 days at 70°.

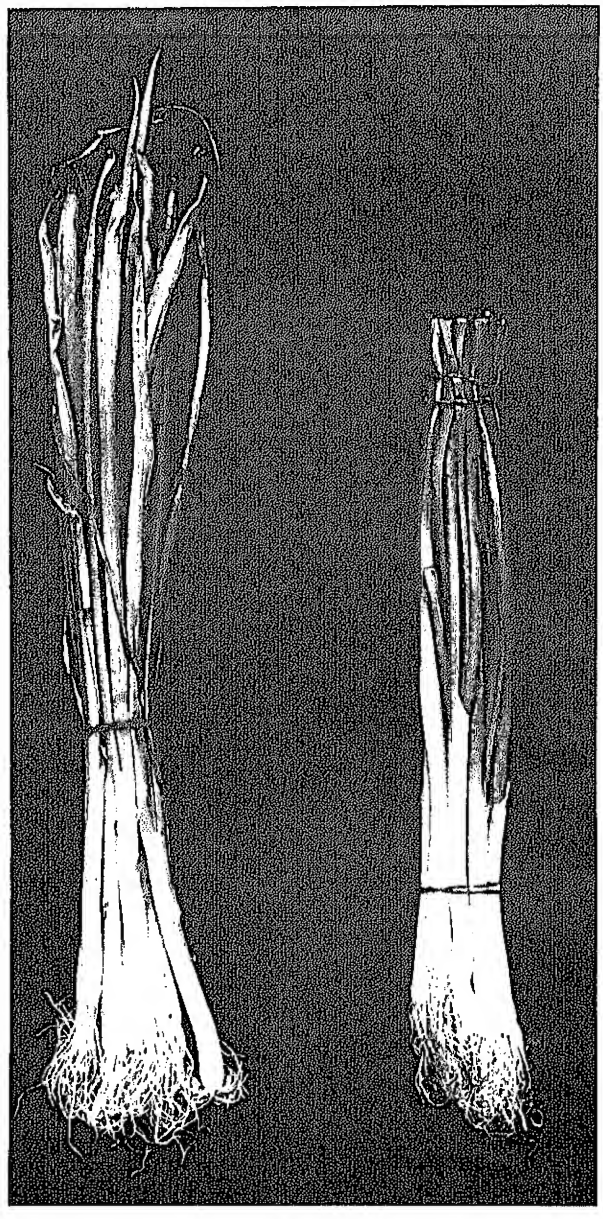

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FIGURE 4.—Ratings of green onions as offered for sale before and after trimming: *Left*, fair; *right*, excellent after trimmed of 21-percent weight of blemished leaves.

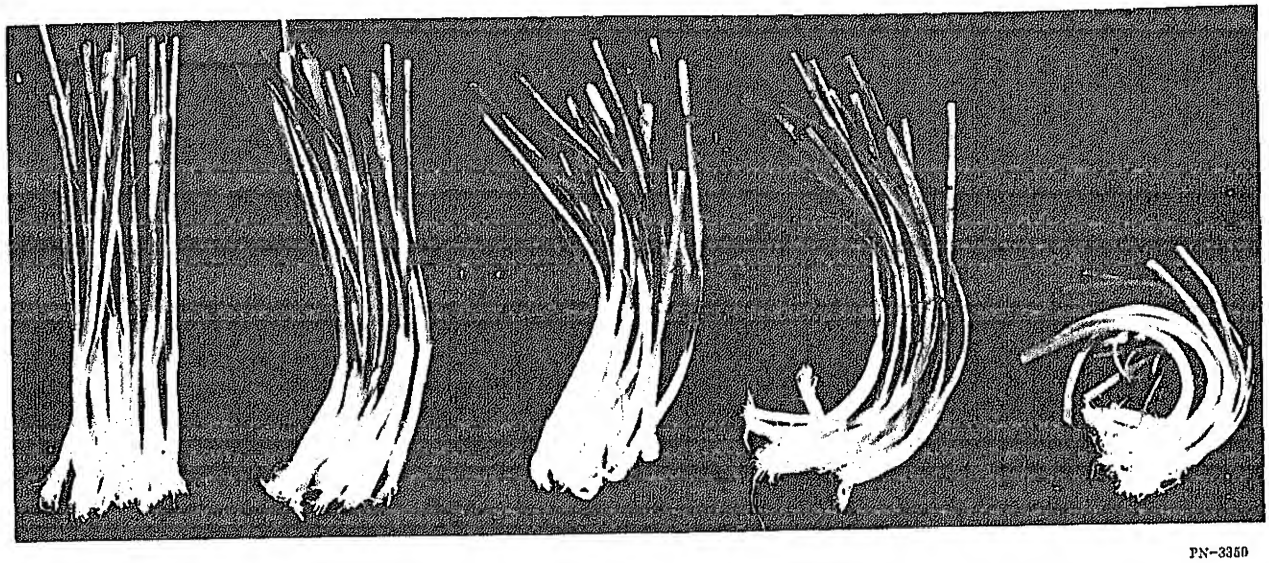

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FIGURE 5.—Ratings for green onions with geotropic curvature (*left to right*): 0=none, 4=slight, 6=moderate, 8=severe, 10=extremely severe.

TABLE 1.—*Elongation of green onions held at 5 temperatures and 85 to 95 percent relative humidity*

Holding temperature (° F)	Length increase[1] after holding for—			
	1 day	2 days	3 days	4 days
	Percent	*Percent*	*Percent*	*Percent*
70	11	16	43. 5	53. 5
60	4. 8	5. 2	23. 2	31. 2
50	2. 8	4. 2	14	20. 2
40	0	. 5	3. 5	4. 8
32	0	0	0	2. 2

[1] Each increase based on 20 onions.

RESPIRATION AND HEAT-EVOLUTION RATES

Respiration and heat-evolution rates for green onions, as measured and calculated by R. E. Hardenburg in 1966 and by H. W. Hruschka in 1969, are summarized in table 2. In both years, R. E. Anderson's adaptations of methods of Brown and Escombe and of Hart, as used by Hruschka (*4*), served to estimate respiration rates of green onion samples weighing 175 grams each. At six temperatures, respiration rates as milligrams of carbon dioxide (CO_2) per kilogram of green onions per hour were multiplied by the factor 220 to convert to British thermal units (Btu) per ton of green onions per 24 hours (*10*).

Green onions respire and produce heat at rates

TABLE 2.—*Respiration and heat-evolution rates for green onions held at 6 temperatures*[1]

Holding temperature (° F)	Respiration rate		Heat-evolution rate	
	Mg CO_2 per kg per h		*Cal per kg per h*	
80	98	210	21.5	46.1
70	79	178	17.3	39.2
60	66	115	14.5	25.2
50	36	62	7.9	13.7
40	17	39	3.8	8.5
32	10	32	2.3	7

[1] Data based on 4 replicates of 3 duplicates each except on 2 replicates at 80° F.

similar to those for strawberries and about midway between rates for apples and asparagus (*10*). Respiration and heat-evolution rates for green onions increased at accelerating rates as the holding temperature was raised. They were 10 times as great at 80° F as at 32°.

STORAGE AND SHELF-LIFE TESTS

Test 1.—Green Onions Stored in Air in Bulk Crates and Cartons and Held in Air After Packaging in Consumer-Unit Polyethylene Bags

Eight polyethylene-lined crates, 12 nonlined crates, and eight waxed cartons were randomly packed with about 250 freshly harvested green onions each at Vineland, N.J., on October 13, 1969. The 25- to 35-inch-long onions were folded to fit the 20-inch inside crate length or trimmed to 15 inches to fit the 15¼-inch carton length (fig. 1). This trimming reduced onion weight by 25 percent. In some U.S. vegetable-production areas, rather than folding the tops, the crate lid is closed on the protruding tops to allow viewing by buyers. Both practices severely damage the tops. At Vineland during loading, four each of the lined crates and waxed cartons of onions were iced. Then all 28 containers of onions were trucked at about 32° F to Beltsville and placed in 32° or 40° storage the same day.

At Beltsville four nonlined, noniced crates of onions were set aside in the 32° F storage room for initial prestorage examination and four were placed at 40° for examination after storage. The four lined, iced crates and the four nonlined, iced waxed cartons were placed in the 32° room at random in one layer completely embedded in snow ice in a drain-equipped sheet-metal tank. The remaining 12 noniced containers of onions, four lined and four nonlined crates and four nonlined waxed cartons, were placed at random on three shelves in the 32° room with no snow ice.

In both the prestorage examination and examinations after 1, 2, 3, and 4 weeks' storage at 32° or 40° F, onions from crates were course trimmed or topped to 15-inch length to conform to the length of onions in cartons. Then some onions from prestorage and from each of the six storage conditions were fine trimmed to remove blemished leaves. Before storage, fine trimming of 5 percent helped appearance.

Forty-eight bunches of 10 onions each from each of the initial and four poststorage examinations (240 bunches) were used in packaging and holding tests to compare iced and noniced onions and polyethylene-wrapped and nonwrapped onions held at 32°, 50°, and 70° F, at about 85 to 95 percent, 75 to 85 percent, and 50 to 75 percent relative humidity, respectively. The onions remaining after each of the 1-, 2-, 3-, and 4-week

examinations were returned to their original storage for removal and examination after 5, 6, 7, and 8 weeks and subsequent packaging and holding tests.

Green onions in storage containers.—In 32° F air storage, green onions were maintained in excellent condition for 4 weeks under top ice in lined crates or in nonlined waxed cartons (table 3). No measurable weight loss from the onions during storage was noted because free water from melting ice prevented or masked weight loss. On opening the bulk containers, the general appearance of the onions was excellent and the containers of onions were rated fully salable. Field-length onions from the crates benefited, however, from coarse trimming to 15-inch length and all onions benefited from the fine trimming to remove slight defects.

In 32° F air storage in crates or cartons with no ice, green onions also held up well and were fully salable for 4 weeks. On removal they were less attractive than those stored at 32° under top ice, but fine trimming made all onions from 32° storage excellent in appearance.

In 40° F air storage in nonlined crates with no ice, green onions were less attractive than those stored at 32°. During 1 to 4 weeks at 40°, onions declined from good to very poor in appearance and from fully salable to nonsalable. Trimming improved appearance, but only enough to make them barely salable after 2, 3, or 4 weeks of storage at 40°.

In other observations, not tabulated here, green onions from containers stored for 5 to 8 weeks in air with or without ice at 32° F or without ice at 40° were poor to extremely poor in appearance and not salable. Onions from 40° storage were badly decomposed and could not be made salable by trimming. Onions from 32° after 5, 6, and 7 weeks' storage were made fully salable by trimming, but after 8 weeks' storage they were barely salable after trimming.

Green onions packaged in consumer units after removal from storage containers.—Residual shelf life (table 4) was greater in green onions that were (1) consumer packaged after 32° F than after 40° storage, (2) taken from top-iced crates than from other containers stored at 32°, (3) wrapped in polyethylene film than left nonwrapped, (4) placed under top ice at 32° after packaging than left without ice at 32°, (5) held at 32° and 90 percent relative humidity than at 50° and 80 percent relative humidity or held at 50° than at 70° and 50 to 75 percent relative humidity.

Green onions from 32° F storage that were bunched and placed in perforated polyethylene bags remained fully salable (1) when subsequently held at 32° with or without top ice for 10 days after 1 to 4 weeks' storage and for 14 days after 1 to 3 weeks' storage, (2) when held at 50° for 3 days after 1 to 4 weeks' storage, and (3) when held at 70° for 1 day after 1 to 3 weeks' storage. Occasionally polyethylene bagged but never nonwrapped onions from 32° storage remained salable after 5 days at 50° or after 2 days at 70°. After removal from 1 week's storage at 40° and packaged in polyethylene, green onions had a shelf life of 14 days at 32°, 3 days at 50°, and 1 day at 70°. No onions were fully salable when packaged after removal from 2 weeks' storage at 40°.

Weight, turgidity, appearance, and shelf life dropped much faster in nonwrapped onions than in polyethylene-wrapped onions. During 3–14 days at 32° F, 3–5 days at 50°, and 1–3 days at 70°, onions in polyethylene bags lost from less than 0.5 percent to 0.9, 1.6, and 1.1 percent of their weight, respectively, and all remained turgid. During the same respective holding times, nonwrapped onions lost 10.4–30.5 percent of their weight at 32°, 16.4–32.4 percent at 50°, and 14.3–33.1 percent at 70°. Green onions remained turgid until over 15.6-percent weight was lost (fig. 6). At weight losses of 16.6–20.2 percent they were less turgid, 20.6–26.5 percent, not turgid, and 34.2–36.6 percent, severely dried (stiff).

Test 2.—Green Onions Stored in Consumer-Unit Polyethylene Bags in Controlled Atmospheres or Air and Held in Air After Storage

Four cartons of White Knight green onions were used in this test. Two cartons came from each of two carload lots harvested on December 3d and 4th, 1969, near Tijuana, Mexico, and Phoenix, Ariz., respectively. In the harvest areas the onions were trimmed to 15-inch length and packed with a topping of crushed ice in waxed cartons. They were transported in railcars to Washington, D.C., under package and top ice and held under ice until the first day of the test on December 15.

TABLE 3.—*Condition of green onions on removal from shipping and storage containers after storage at 32° or 40° F and 85 to 95 percent relative humidity and after trimming*

Storage temperature, container, icing, and weeks stored	Observed at opening of storage containers		Observed after trimming of onions	
	Cumulative weight loss during storage [1]	General appearance of onions in container before trimming [2]	Weight removed by fine trimming [1]	General appearance of onions after fine trimming and bunching [2]
32° F	*Percent*	*Rating*	*Percent*	*Rating*
Wirebound crate with polyethylene liner:				
Top iced:				
1	---	Excellent	10. 6	Excellent.
2	---	do	11. 1	Do.
3	---	do	8. 5	Do.
4	---	do	13	Do.
Noniced:				
1	2. 6	do	12. 0	Do.
2	3. 6	Very good	7. 6	Do.
3	3. 7	do	11. 4	Do.
4	5. 9	Good	12. 8	Do.
Wirebound crate:				
Nonlined, noniced:				
1	5. 2	Excellent	6. 7	Do.
2	8. 6	Very good	7. 6	Do.
3	9. 2	do	11. 5	Do.
4	10. 5	Good	16. 9	Do.
40° F				
Wirebound crate:				
Nonlined, noniced:				
1	2. 5	do	16. 6	Very good.
2	5. 5	Fair	24. 6	Fair.
3	5. 8	Poor	22. 3	Do.
4	7. 7	Very poor	22. 4	Do.
32° F				
Waxed carton nonlined:				
Top iced:				
1	---	Excellent	7. 8	Excellent.
2	---	do	11. 2	Do.
3	---	do	12. 1	Do.
4	---	do	10. 3	Do.
Noniced:				
1	1. 4	do	9. 2	Do.
2	3. 6	Very good	7. 9	Do.
3	3. 8	do	13. 7	Do.
4	7	Good	21. 9	Do.

[1] Based on percent weight loss for coarse and fine trim.

[2] Freshly harvested to slightly less fresh onions were rated excellent to good and were fully salable. Onions blemished with increasing amounts of mold, slime, curvature, and yellowing were fair, poor, or very poor and barely salable, nonsalable, and nonsalable, respectively.

TABLE 4.—*Storage life at 32° or 40° F during which green onions in storage containers were maintained with sufficient residual shelf life to remain fully salable after consumer packaging and holding for indicated days at 3 temperatures* [1]

Wrapping,[2] icing, holding temperature (F), and shelf life (days) after consumer packaging	Storage life at 32° F when held in—					Storage life at 40° F when held in nonlined, noniced crate
	Polyethylene-lined crate		Nonlined, noniced crate	Waxed carton		
	Top iced	Noniced		Top iced	Noniced	
	Weeks	*Weeks*	*Weeks*	*Weeks*	*Weeks*	*Weeks*
Bunches before holding, 0 day	4	4	4	4	4	1
Film bag:						
Top iced, 32°:						
3	4	4	4	4	4	1
5	4	4	4	4	4	1
7	4	4	4	4	4	1
10	4	4	4	3	4	1
14	3	3	3	2	2	1
Noniced, 32°:						
3	4	4	4	4	4	1
5	4	4	3	4	4	1
7	4	4	3	4	4	1
10	4	4	3	4	4	1
14	3	3	3	1	1	1
Noniced, 50°, 3	4	3	3	3	3	1
Noniced, 70°, 1	3	3	3	1	1	1
Nonwrapped:						
Top iced, 32°:						
3	4	4	4	4	4	1
5	4	4	4	4	4	1
7	4	4	4	3	3	1
10	4	4	4	3	3	1
14	2	2	3	2	3	1
Noniced, 32°:						
3	4	4	4	4	4	1
5	4	4	4	4	4	1
7	3	4	3	3	3	1
10	2	2	2	0	1	0
14	(3)	(3)	(3)	(3)	(3)	(3)
Noniced, 50°, 3	3	1	1	1	1	1
Noniced, 70°, 1	3	1	1	1	1	1

[1] 32°, 50°, and 70° F at 90, 80, and 50 to 70 percent relative humidity, respectively.

[2] Consumer-unit polyethylene film bags each perforated with sixteen 3/16-inch holes (fig. 3); nonwrapped bunches of onions each secured by 2 rubberbands (fig. 4).

[3] Not salable after 14 days.

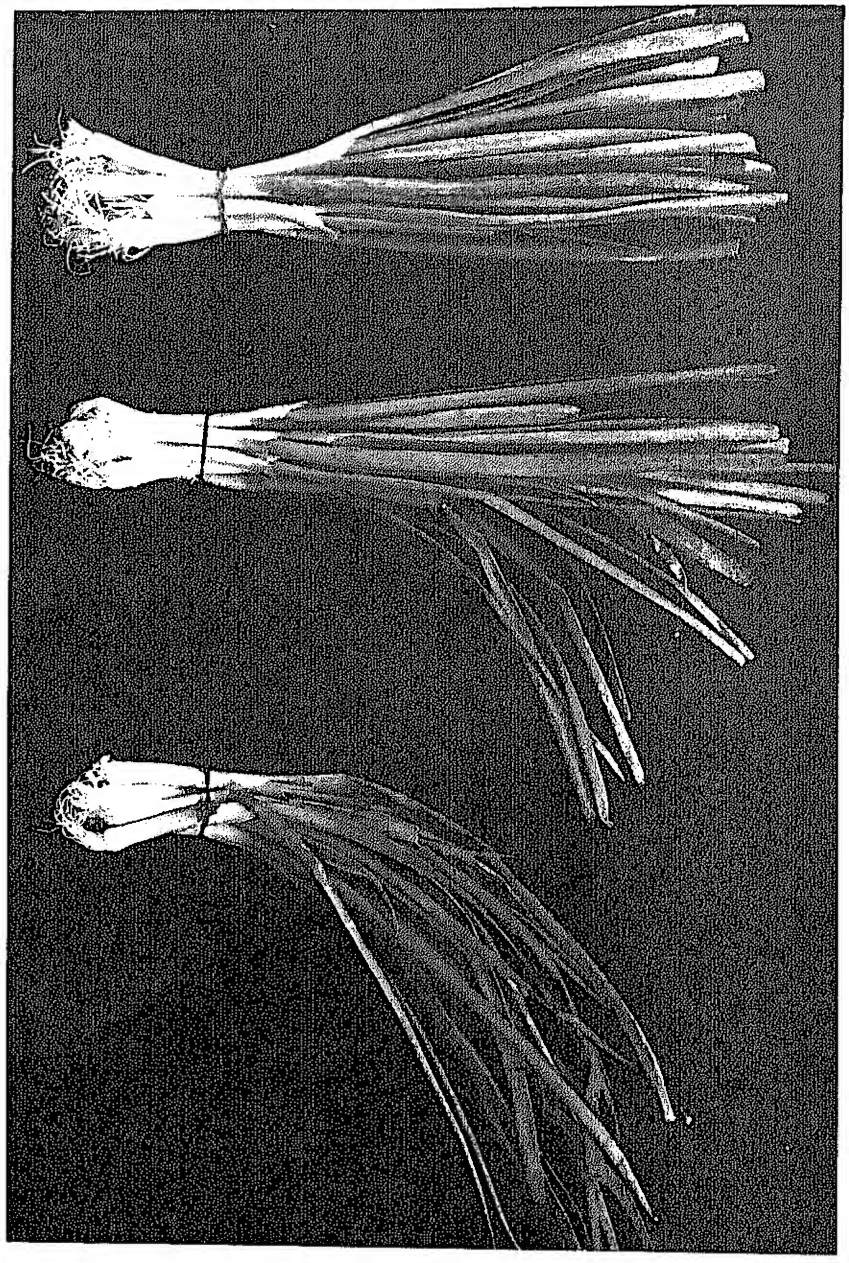

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FIGURE 6.—Drooping in bunches of green onions due to weight loss and wilting. Ratings of wilting (*top to bottom*): 0=none (turgid), 4=slight, 8=severe.

At Beltsville the onions were sorted and trimmed to be free of such blemishes as decayed, bruised, or yellowed leaves. Seventy-two 10-stalk bunches were assembled from these blemish-free onions, 36 bunches from each of the two harvest areas. The bunches were secured with rubberbands and left nonwrapped or bagged as listed in table 5. Three bunches from each of the two harvest areas were placed in each of 12 storage chambers within one storage area at 32° F. Eight chambers were nonicod storage drums, four from each of two shelves (fig. 7). Four chambers were iced waxed

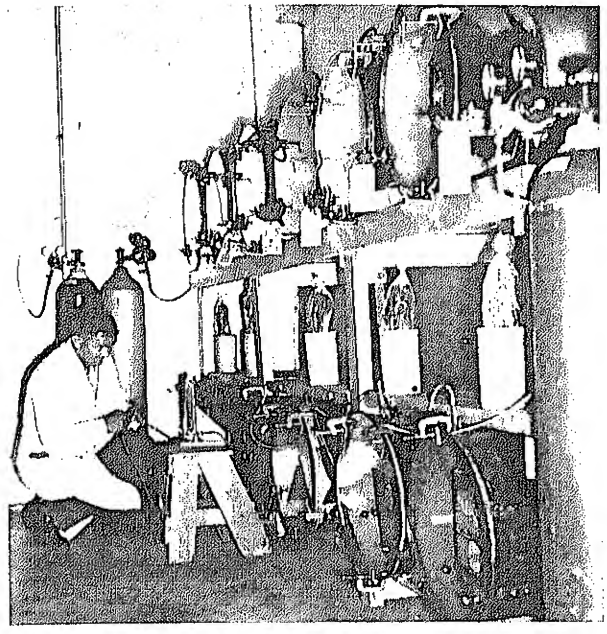

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FIGURE 7.—Technician reading flow meter while adjusting amount of nitrogen or combined oxygen and carbon dioxide gases leaving cylinders to enter controlled atmosphere storage chambers.

cartons buried in snow ice, two per layer in a drain-equipped sheet-metal tank (not shown). These cartons of iced onions were in still air. The eight drums holding noniced onions were supplied with flowing (1) air, (2) 1–5 CA (1 percent oxygen (O_2) with 5 percent carbon dioxide (CO_2) controlled atmosphere), or (3) 5–15 CA (5 percent O_2, 15 percent CO_2). The flow from compressed gas cylinders averaged 5 liters per hour to each drum of 113.6-liter (30 gal.) capacity.

Twenty-four bunches (from two harvest areas by two chambers by six treatment combinations) were removed after each storage period of 4, 6, and 8 weeks. Onions from each bunch were examined on removal from storage, after holding 1 additional week at 32° F outside the chambers, and subsequently after 1 more day outside at 70°. The resulting 216 data bits for each quality criterion were analyzed as split split plots and are summarized in table 5.

Throughout the test the onion roots were generally fresh, white, turgid, and free of decay. Bulbs were firm, white, and excellent in appearance. Before storage all onion tops were free of decay, fresh, green, turgid, normally straight, and excellent in appearance.

Weight loss was retarded or prevented by using nonperforated polyethylene bags or top ice. Nonwrapped onions removed from top ice protection lost over 7-percent weight during 1 week at 32° F and 85 to 95 percent relative humidity and nearly 20 percent after 1 subsequent day at 70° and 50 to 75 percent relative humidity. Perforated polyethylene bags allowed about 2.5-percent weight loss from onions during 4 to 8 weeks' storage in chambers supplied with flowing air, 1–5 CA, or 5–15 CA, and allowed from 1.1- to 1.9-percent weight loss from onions subsequently held in air outside the chambers. All onions in polyethylene bags remained turgid throughout the tests. Onions in nonwrapped bunches were turgid at all examinations except after 1 day at 70°, when they were limp from 19.6-percent weight loss (fig. 6).

Controlled atmospheres (1–5 CA and 5–15 CA) were significantly more effective in maintaining green onion quality than either flowing air without ice or still air with top ice placed over the cartons of onions.

Green onions from 1–5 or 5–15 controlled atmosphere storage developed practically no yellowing and only slight curvature during storage and holding. An average of less than one onion per bunch developed some decay during storage and holding at 32° F and three or four onions per bunch had some decay after 1 subsequent day at 70°. On removal from 4, 6, or 8 weeks' controlled atmosphere storage, general appearance of the onions was excellent. It was good to excellent after 1 week at 32° following removal from controlled atmosphere storage and fair to good after 1 subsequent day at 70°. The onions from controlled atmosphere storage were rated fully salable throughout 4, 6, or 8 weeks at 32° storage and at 32° and 70° holding in this test. They appeared as good as or better than most onions offered for retail sale. They were improved to excellent by a light trim.

Onions from the other four storage treatments developed trace and slight yellowing and slight, moderate, and severe curvature during storage and holding. Decay was found in four to seven onions per bunch on removal from storage, in six to eight onions per bunch after 1 more week at 32° F, and in eight to 10 onions per bunch after 1 subsequent day at 70°. General appearance was fair and onions were barely salable on removal after only 4 weeks'

TABLE 5.—*Condition of green onions after storage in consumer wrap in controlled atmospheres or air at 32° F and after holding in air at 2 temperatures* [1]

Storage atmosphere [2] and consumer wrap	Weight loss (cumulative)				Decay (cumulative)			
	At removal	After 1 week at 32° F [3]	After 1 day at 70° F [4]	Average	At removal	After 1 week at 32° F [3]	After 1 day at 70° F [4]	Average
Flowing air:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Perforated polyethylene	2.2	3.9	5.4	3.9 b	68	82	94	81 a
Nonperforated polyethylene	.6	1.8	2.7	1.7 c	34	59	78	57 b
Flowing 1–5 CA, perforated polyethylene	2.6	4.5	5.7	4.3 b	2	7	29	13 c
Flowing 5–15 CA, perforated polyethylene	2.4	3.7	4.8	3.6 b	2	10	39	17 c
Still air, onions under top ice:								
Perforated polyethylene	0	1.8	3.2	1.7 c	53	63	93	70 a
Nonwrapped	0	7.4	19.6	9 a	55	74	95	75 a
Holding average	1.3 c	3.8 b	6.9 a		36 c	49 b	71 a	
Storage average:								
4 weeks				3.8 ab				42 c
6 weeks				3.4 b				51 b
8 weeks				4.8 a				63 a
	Curvature rating [5]				Yellowing rating [5]			
Flowing air:								
Perforated polyethylene	6.5	7.8	7.3	7.2 a	1	.8	2.5	1.4 a
Nonperforated polyethylene	4.7	5.1	5.8	5.2 b	1	1.2	2.2	1.5 a
Flowing 1–5 CA, perforated polyethylene	3.7	3.9	4.1	3.9 cd	0	0	.2	.06 b
Flowing 1–15 CA, perforated polyethylene	3	3.4	3.7	3.4 d	0	0	.2	.06 b
Still air, onions under top ice:								
Perforated polyethylene	4.2	4.8	5	4.7 bc	.5	1.5	2.7	1.6 a
Nonwrapped	4.5	5.3	5.9	5.3 b	1.3	1.6	2.7	1.9 a

Holding average	4.4 b	5.1 a	5.3 a		.6 b	.8 b	1.7 a	
Storage average:								
4 weeks				4.9 a				.9 a
6 weeks				5.2 a				1.1 a
8 weeks				4.7 a				1.2 a
	General appearance rating [6]				Salability [6]			
Flowing air:								
Perforated polyethylene	4.6	3.9	2.8	3.8 c	No	No	No	No c
Nonperforated polyethylene	6.2	5.7	4.2	5.4 b	Barely	Barely	No	No+ b
Flowing 1–5 CA, perforated polyethylene	9.5	9.2	6.8	8.5 a	Yes	Yes	Yes	Yes a
Flowing 1–15 CA, perforated polyethylene	9.7	9.2	6.7	8.6 a	Yes	Yes	Yes	Yes a
Still air, onions under top ice:								
Perforated polyethylene	5.5	4.7	3.6	4.6 b	Barely	No	No	No+ b
Nonwrapped	3.1	3.9	3.2	4.1 c	No	No	No	No c
Holding average	6.8 a	6.1 b	4.6 c		Yes a	Barely b	No c	
Storage average:								
4 weeks				6.5 a				Yes a
6 weeks				5.8 b				Barely b
8 weeks				5.2 c				No c

[1] Data based on 12 bunches of green onions except atmosphere holding and storage averages, which are based on 3 or 6 multiples of 12 bunches. Duncan's multiple-range test of significance at 5-percent level; comparable averages followed by no letters in common are significantly different (*6*).

[2] 1–5 CA=1 percent oxygen with 5 percent carbon dioxide controlled atmosphere; 5–15 CA=5 percent oxygen with 15 percent carbon dioxide controlled atmosphere.

[3] 85 to 95 percent relative humidity.

[4] 50 to 75 percent relative humidity.

[5] 0=none, 2=trace, 4=slight, 6=moderate, 8=severe, 10=extremely severe.

[6] 10=excellent, 8=good, 6=fair, 4=poor, 2=very poor, 0=badly decomposed.

storage either in perforated polyethylene bags in chambers supplied with flowing air or in nonwrapped bunches under top ice in chambers in still air. Onions, stored in sealed polyethylene bags in flowing air or in perforated polyethylene bags under top ice in still air, maintained acceptable appearance and were salable at removal from storage after 4 weeks plus 1 week at 32° outside of the storage chambers. Beyond these storage and holding periods, appearance was unacceptable and onions were unsalable.

Test 3.—Green Onions Stored in Waxed Cartons in Controlled Atmosphere or Air and Held in Consumer-Unit Polyethylene Bags in Air After Storage

Sixteen cartons of White Knight green onions were used in this test. They were moved from Arizona and Mexico in railcars under package- and top-ice refrigeration. Four cartons came from each of four separate carloads unloaded March 2, 9, 16, and 25, 1970, in Washington, D.C., and trucked to Beltsville.

After each arrival at Beltsville, the onions from the four cartons from each replicate load were sorted to remove blemished bunches and trimmed to 15-inch length. The blemish-free bunches of onions were randomly placed in three of the waxed cartons and four bunches from each of the three cartons were removed immediately for initial examination and prestorage holding tests. The three cartons with the remaining blemish-free onions were placed in three storage locations at 32° F.

The three storage locations for each replicate consisted of two noniced chambers (of 12 shown in fig. 7) supplied with either flowing air or flowing 1–5 CA and one area in a drain-equipped sheet-metal tank (not shown) that was in still air and filled with top ice for immersing the carton of green onions. When onions from the four replicates were under test, eight noniced chambers in figure 7 were used together with four submerged locations in the ice tank. After storage periods of 4, 6, 8, 10, and 12 weeks, four bunches from the carton in each storage chamber were examined, trimmed, and reexamined to determine storage effects. The bunches were then consumer packaged in polyethylene bags or left nonwrapped for holding at 32° and 70° F, both at 85 to 95 percent relative humidity. Each of the four bunches was examined before holding and after holding for 1, 2, and 3 days.

The 72 data bits for the storage tests and 1,152 data bits for the holding tests were analyzed as split plots and split, split, split plots and are summarized in tables 6 and 7.

Green onions in storage containers.—When placed in storage chambers in test 3, all bunches of onions were excellent in appearance and fully salable (table 6). They were even more attractive after fine trimming. At 32° F the general appearance and condition of onions were maintained much better in flowing 1–5 CA than in flowing air without ice or in still air with top ice over the cartons of onions. In 1–5 CA, onions were excellent after storage for 4 weeks, fair after 10 weeks, and poor after 12 weeks. They were excellent, very good to excellent, and good, respectively, after fine trimming. Onions from flowing air or still air storage with top ice added required more fine trimming and had significantly lower appearance ratings than onions from 1–5 CA. Trimmed onions from iced storage appeared better than those stored without ice in flowing air.

Green onions packaged in consumer units after removal from storage container.—After consumer packaging, green onions from 1–5 CA storage held up better than top iced onions from still air storage, which held up better than onions from storage in flowing air without ice (table 7). Storage in 1–5 CA largely prevented curvature of onions, whereas storage in air with or without ice allowed considerable curvature. The effect of 1–5 CA in preventing curvature apparently persisted even after removal from the storage chambers. Green onions that were consumer packaged in polyethylene bags held up better than nonwrapped onions. Wrapped and nonwrapped onions held up much better at 32° F than at 70°.

As indicated in table 7, but not tabulated in detail elsewhere, holding temperature affected decay to a considerable extent, whereas consumer wrap had little effect. An average of less than 1-percent decay developed in wrapped and nonwrapped bunches of onions held 1 to 3 days at 32° F. At 70°, decay in wrapped and nonwrapped onions averaged about 11, 60, and 85 percent after 1, 2, and 3 days, respectively.

TABLE 6.—*General appearance ratings of green onions before and after fine trimming and percent weight of blemished leaves removed by fine trimming following storage at 32° F and 90 to 95 percent relative humidity in waxed cartons in chambers supplied with various atmospheres* [1]

Weeks in storage	Stored in—			Average
	Still air under top ice	Flowing air, no ice	Flowing 1–5 CA,[2] no ice	
	PRETRIM APPEARANCE RATING [3]			
0	9.9 a	9.9 a	9.9 a	9.9 a
4	5.5 de	4.4 e	9.6 a	6.5 b
6	2.8 f	2.2 f	8.5 ab	4.5 c
8	2.8 f	1.8 f	7.3 bc	3.9 c
10	1 f	1 f	5.8 cd	2.8 d
12	1 f	1 f	4.6 e	2.2 d
Average	3.8 b	3.4 b	7.7 a	---
	POSTTRIM APPEARANCE RATING [3]			
0	10 a	10 a	10 a	10 a
4	9.9 a	9.5 ab	10 a	9.8 a
6	9.5 ab	8.1 b	10 a	9.2 a
8	8.4 ab	5.8 cd	9.4 ab	7.9 b
10	6.4 c	5.4 cd	9.5 ab	7.1 c
12	5.9 cd	4.8 d	8.1 b	6.3 c
Average	8.4 b	7.3 c	9.5 a	---
	PERCENT WEIGHT REMOVED BY TRIMMING			
0	13.2 fg	11 g	12 g	12.1 d
4	32.5 de	36 de	17.2 fg	28.6 c
6	38.8 cde	39.8 bcd	17.2 fg	32 c
8	46.2 abcd	46.2 abcd	26 ef	39.5 b
10	50.2 abc	52.2 abc	32.2 de	44.9 ab
12	53.2 ab	56.5 a	44.5 abcd	51.4 a
Average	39 a	40.3 a	24.9 b	---

[1] Data based on 16 bunches of green onions (4 replicates by 4 duplicates) except averages, which are based on 3 and 6 multiples of 16 bunches. Duncan's multiple-range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (*6*).

[2] 1 percent oxygen with 5 percent carbon dioxide controlled atmosphere.

[3] 10=excellent, 8=good, 6=fair, 4=poor, 2=very poor, 0=badly decomposed; 6=barely salable, over 6=salable, under 6=not salable.

Shelf-life and general-appearance ratings with contributing condition factors generally worsened with increase in previous storage time and holding time.

Under the best conditions tested, green onions removed from cartons before storage and after 4 to 12 weeks' storage in 1–5 CA were rated excellent and excellent to good in general appearance immediately after trimming and consumer packaging. Green onions wrapped in polyethylene on removal from CA remained excellent and excellent to good for 3 days' shelf life at 32° F or for 1 day's shelf life at 70°.

Test 4.—Green Onions Stored in Waxed Cartons in Controlled Atmosphere or 100 Percent Nitrogen and Held in Consumer Wrap in Air After Storage

Eight crates of Beltsville Bunching variety green onions, two from each of four truckloads, each from a separate Vineland, N.J., farm, were used in this test. The onions were trucked under top ice to Washington, D.C., on June 29, 1970, and hauled to Beltsville on the same day. At Beltsville the onions from each replicate pair of crates were sorted to remove blemished bunches.

TABLE 7.—*Summary of effects of storage and holding conditions on quality of green onions on removal fro storage in 3 atmospheres at 32° F*[1]

Storage and holding conditions	General appearance[2]	Weight loss[3]	Wilting[4]	Yellowing[4]	Curvature[4]	Decay[5]
	Rating	*Percent*	*Rating*	*Rating*	*Rating*	*Percent*
Storage atmosphere:						
Flowing air	6.3 c	5.3 c	1 b	3 b	6.6 a	17.6 b
Flowing 1–5 CA[6]	7.8 a	6.8 a	2.3 a	1.3 a	.9 c	23.1 a
Still air, onions under top ice.	7.1 b	5.6 b	1 b	2 ab	4.8 b	18.6 b
Storage time (weeks):						
0	8.1 a	6.4 a	2.2 a	1.6 b	.9 c	17.5 b
4	8 a	6.8 a	1.9 ab	1.6 b	3.7 b	23.8 a
6	7.7 a	6.6 a	1.6 b	1.5 b	4.6 a	20.6 ab
8	6.8 b	5.2 b	1.1 c	2.4 ab	4.9 a	19 a
10	6.1 c	5.1 b	1 c	2 b	5.4 a	18.4 ab
12	5.7 c	5.2 b	1 c	3.3 a	5.1 a	19.4 ab
Consumer wrap:						
Perforated polyethylene.	7.2 a	1.1 b	0 b	1.9 b	4.1 a	19.5 b
Nonwrapped	6.9 b	10.7 a	2.9 a	2.2 a	4.1 a	20.1 a
Holding temperature (F):						
32°	8.2 a	4.1 b	1.2 b	1 b	3.8 b	.5 b
70°	5.9 b	7.7 a	1.7 a	3.1 a	4.4 a	39 a
Holding time (days):						
0	8.4 a	0 d	0 d	1 d	3.6 c	0 d
1	7.6 b	4.7 c	1.2 c	1.8 c	4.1 b	5.3 c
2	6.4 c	7.9 b	2 b	2.7 b	4.3 a	30.1 b
3	5.9 d	11 a	2.6 a	2.9 a	4.4 a	43.7 a

[1] Data based on 1,152 observations for each condition criterion. Averages for each of the 5 main effect elements; summarize data ranging over other 4 main effects. Averages include observations on following conditions and bunches of onions: Storage atmosphere 384, storage time 192, consumer package wrap 576, holding temperature 576, and holding time 288. Duncan's multiple-range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (*6*).

[2] 10=excellent, 8=good, 6=fair, 4=poor, 2=very poor, 0=badly decomposed; 6=barely salable, over 6=salable, under 6=not salable.

[3] Based on onion weight when consumer packaged an after holding at 32° or 70° F and 85 to 95 percent relativ humidity.

[4] 0=none, 2=trace, 4=slight, 6=moderate, 8=severe 10=extremely severe (figs. 5 and 6).

[5] Based on number of stalks having any leaves wit slight to extremely severe decay and total stalks in bunc

[6] 1 percent oxygen with 5 percent carbon dioxide con trolled atmosphere.

Then the blemish-free bunches were trimmed to 15-inch length to easily fit lengthwise in waxed corrugated cartons.

Twelve waxed cartons were each fitted lengthwise with a waxed corrugated-cardboard upright partition to make 24 onion storage compartments, two per carton for each of six storage chambers on each of two storage shelves (fig. 7). Twenty-four bunches (six per replicate) were used for initial examinations and 144 bunches (36 per replicate or 48 for each of three removals) were used for subsequent examinations. From replicates 1 an 2, six bunches of onions were placed in each of th right and left compartments, respectively, of th six cartons for storage in the six chambers on th upper shelf in a 32° F storage room. Bunches c onions from replicates 3 and 4 were similarl placed in carton compartments in six chambe on the lower shelf.

Half of the 12 chambers, three on the uppe shelf and three on the lower shelf, were each sup plied during storage with flowing atmospheres c

100 percent nitrogen and half were supplied with 1 percent oxygen with 5 percent carbon dioxide (1–5 CA) at 5 liters per hour. After each storage period of 2, 4, or 6 weeks, four of the chambers (one nitrogen and CA chamber from each shelf) were opened and all 48 bunches were removed for examination and holding tests.

After each prestorage and poststorage examination, the bunches were fine trimmed, reexamined, and consumer packaged in polyethylene bags, in polyvinyl chloride sleeves, or in no wrap (fig. 3). The nonwrapped bunches were each secured with two rubberbands (fig. 4). Consumer-packaged bunches of green onions were examined immediately after packaging and subsequently after holding at 32° or 70° F for 1, 2, or 3 days.

The data were analyzed and are summarized in tables 8–10.

Green onions in storage containers.—Following initial sorting and trimming, all bunches of onions in test 4 were excellent in appearance and fully salable (table 8). They were made more attractive by fine trimming to remove trace-blemished leaves comprising about 13 percent of bunch weight.

On removal after 2, 4, or 6 weeks' storage in 100 percent nitrogen, onions were good, fair, and poor, respectively, in appearance. But fine trimming of about 20-, 27-, and 35-percent weight raised ratings to excellent, excellent, and very good, respectively. Comparable onions from CA storage were slightly better than from nitrogen storage. However, in other unreported observations the reverse was true. The overall differences between nitrogen and CA stored onions were never statistically significant.

Green onions packaged in consumer units after removal from storage containers.—Green onions that were trimmed and consumer packaged before storage or after 2, 4, or 6 weeks in 32° F storage in either 100 percent nitrogen or 1–5 CA held up about equally well (tables 9 and 10). Differences in quality, after holding, that were attributable to storage atmospheres were sometimes statistically but never practically significant.

General appearance and condition factors were affected mainly by holding temperature, type of wrap, and holding time. When held at 32° F, polyethylene-bagged green onions were excellent to very good for 3 days, whereas nonwrapped onions were fair to good after 3 days. When held at 70°, polyethylene-bagged green onions were good to very good after 1 day but only fair or poor after 2 days, whereas the nonwrapped onion bunches were fair to good after 1 day and generally

TABLE 8.—*General appearance ratings of green onions before and after fine trimming and percent weight of blemished leaves removed by fine trimming following storage at 32° F and 90 to 95 percent relative humidity in waxed cartons in chambers supplied with flowing nitrogen or 1–5 controlled atmosphere* [1]

Weeks in storage	Stored in—		Average
	Nitrogen	1–5 CA[2]	
	PRETRIM APPEARANCE RATING[3]		
0	10 a	10 a	10 a
2	8 ab	9 a	9 b
4	6.2 bc	6.3 bc	6.2 c
6	4.2 c	6.5 b	5.4 d
Average	7.1 a	7.9 a	----------
	POSTTRIM APPEARANCE RATING[3]		
0	10 a	10 a	10 a
2	10 a	10 a	10 a
4	9.8 ab	9.8 ab	9.8 a
6	9.4 b	9.9 ab	9.6 a
Average	9.8 a	9.9 a	----------
	PERCENT WEIGHT REMOVED BY TRIMMING		
0	13.1 d	13.1 d	13.1 d
2	19.6 c	19.3 c	19.4 c
4	27.5 b	27.6 b	27.6 b
6	34.9 a	30 ab	32.4 a
Average	23.8 a	22.5 a	----------

[1] Data based on 24 bunches of green onions except averages, which are based on 2 and 4 multiples of 24 bunches. Zero (0) week values are duplicates. Duncan's multiple-range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (*6*).

[2] 1 percent oxygen with 5 percent carbon dioxide controlled atmosphere.

[3] 10=excellent, 8=good, 6=fair, 4=poor, 2=very poor, 0=badly decomposed; 6=barely salable, over 6=salable, under 6=not salable.

poor after 2 days. Appearance ratings were little affected by decay since easily trimmed tip decay was included in the total percent and tip decay did not greatly affect appearance.

Green onions in heat-shrinkable polyvinyl chloride sleeve wrap held up as well as or slightly better than onions in perforated polyethylene bags. During holding, weight loss from green onions was largely prevented by the polyethylene bag wraps. The sleeve wraps allowed an average of about 3-percent weight loss, whereas non-wrapped bunches lost about 8-percent weight. Only a trace of wilting resulted from this weight loss.

TABLE 9.—*Summary of effects of storage and holding conditions on quality of green onions that were consumer packaged on removal from storage in 2 atmospheres at 32° F*[1]

Storage and holding conditions	General appearance [2]	Weight loss [3]	Yellowing [4]	Curvature [4]	Decay [5]
	Rating	*Percent*	*Rating*	*Rating*	*Percent*
Storage atmosphere:					
Nitrogen	8.1 a	3.7 a	1.7 a	4.3 a	22.6 a
1–5 CA [6]	8.3 a	3.8 a	1.3 b	3.8 a	24 a
Storage time (weeks):					
0	8.2 a	4.9 a	1.3 a	2.7 c	12.3 c
2	8.3 a	3.4 b	1.5 a	3.5 b	24.5 ab
4	8.2 a	3.4 b	1.6 a	3.9 b	24.8 a
6	8.2 a	3.4 b	1.3 a	4.8 a	20.5 bc
Consumer wrap:					
Perforated polyethylene bag	8.4 a	.5 c	1.4 b	4.2 b	23.3 ab
Polyvinyl chloride sleeve	8.5 a	3 b	1.4 b	3.6 c	20.8 b
Nonwrapped	7.8 b	7.8 a	1.6 a	4.4 a	25.8 a
Holding temperature (F):					
32°	9.6 a	3.5 b	.3 b	2.9 b	0 b
70°	6.9 b	4 a	2.7 a	4.2 a	46.6 a
Holding time (days):					
0	9.8 a	0 d	.5 d	3.6 d	0 d
1	9 b	2.4 c	1.5 c	4 c	10.1 c
2	7.5 c	5 b	1.9 b	4.2 b	36.1 b
3	6.5 d	7.5 a	2.2 a	4.4 a	47 a

[1] Data based on 576 observations for each condition criterion. Averages for each of the 5 main effect elements; summarize data ranging over other 4 main effects. Averages include following conditions and bunches of onions: Storage atmosphere 288, storage time 144, consumer package wrap 192, holding temperature 288, and holding time 144. Duncan's multiple-range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (*6*).

[2] 10=excellent, 8=good, 6=fair, 4=poor, 2=very poor, 0=badly decomposed; 6=barely salable, over 6=salable, under 6=not salable.

[3] Based on onion weight when consumer packaged and after holding at 32° or 70° F and 85 to 95 percent relative humidity.

[4] 0=none, 2=trace, 4=slight, 6=moderate, 8=severe, 10=extremely severe.

[5] Based on number of stalks having any leaves with trimmable leaf tip decay or slight to extremely severe leaf blade decay and total stalks in bunch.

[6] 1 percent oxygen with 5 percent carbon dioxide controlled atmosphere.

TABLE 10.—*Effects of storage and holding conditions on appearance ratings of green onions that were consumer packaged on removal from storage in 2 atmospheres at 32° F and held at 2 temperatures with 85 to 95 percent relative humidity* [1]

Consumer wrap and days held after consumer packaging	Packaged after storage in nitrogen and held at—		Packaged after storage in 1–5 CA [2] and held at—	
	32° F	70° F	32° F	70° F
Perforated polyethylene bag:	*Rating* [3]	*Rating* [3]	*Rating* [3]	*Rating* [3]
0	9.7 ab	9.8 a	9.9 a	9.9 a
1	9.7 ab	8.3 fg	10.0 a	8.8 def
2	9.7 ab	5.8 j	9.9 a	5.3 jk
3	9.2 abcd	4.3 l	9.9 a	3.4 m
Average	9.6 bc	7.0 e	9.9 ab	6.8 ef
Polyvinyl chloride sleeve:				
0	9.8 a	9.8 a	9.9 a	9.9 a
1	9.8 a	8.6 ef	10.0 a	8.9 cdef
2	9.8 a	5.8 j	10.0 a	5.9 j
3	9.8 a	3.9 lm	10.0 a	4.1 l
Average	9.8 ab	7.0 e	10.0 a	7.2 e
Nonwrapped:				
0	9.8 a	9.7 ab	9.9 a	9.9 a
1	9.6 abc	7.3 h	9.9 a	7.5 h
2	9.0 bcde	5.1 k	9.5 abc	4.4 l
3	6.7 i	4.2 l	7.9 gh	4.0 lm
Average	8.8 d	6.6 fg	9.3 c	6.5 g
Atmosphere×temperature average	9.37 b	6.89 c	9.74 a	6.84 c

Consumer wrap	Atmosphere×wrap (32°+70°) average	Atmosphere×wrap (32°+70°) average	Wrap average
	Rating [3]	*Rating* [3]	*Rating* [3]
Perforated polyethylene bag	8.30 b	8.40 ab	8.35 a
Polyvinyl chloride sleeve	8.43 ab	8.59 a	8.51 a
Nonwrapped	7.67 c	7.89 c	7.78 b
Storage atmosphere average	8.13 a	8.29 a	

[1] Data based on 576 observations. Each of the 48 ratings is average of 12 data bits (4 replicates×3 storage periods). Averages are based on 4, 8, 12, and 24 multiples of 12 data bits. Duncan's multiple-range test of significance at 5-percent level; comparable values followed by no letters in common are significantly different (*6*).

[2] 1 percent oxygen with 5 percent carbon dioxide controlled atmosphere.

[3] Ratings: 10=excellent, 8=good, 6=fair, 4=poor, 2=very poor, 0=badly decomposed; 6 (fair)=barely salable, over 6=salable, under 6=not salable.

DISCUSSION

The storage and shelf life of fresh green onions can be extended markedly by proper handling, packaging, and refrigeration. For best quality maintenance, green onions should be kept at 32° F (0° C) and high relative humidity (90–95 percent or above) throughout storage and marketing. Green onions may be protected from moisture loss and temperature rise by transporting and storing under top ice in waxed cartons containing a topping of snow ice separated from the onions by a layer of parchment paper. Following storage, green onions should be packaged in perforated moisture-retentive film and refrigerated to maintain freshness during retailing and home storage.

Wilting in green onions is noticeable when 15-percent weight is lost; at 20-percent weight loss, wilting is objectionable. In other crops, such as rhubarb and kale, wilting is visible when weight loss is under 5 percent and is objectionable at 5 to 10 percent.

Trimming 25- to 35-inch-long field-grown green onions in the growing area to fit 20-inch crate length or 15¾-inch waxed carton length can reduce shipping weight, package size, and refrigeration costs by about 25 percent.

At 70° F (21.1° C), trimmed green onions respire and produce heat at 17,000 to 39,000 Btu per ton per day—about six to eight times the rate for green onions held at 32°. At 80° (26.7°), respiration is 10 times that at 32°. These higher rates partly explain why green onions held at 70° or 80° deteriorate faster than at 32°.

Except for a storage period of no longer than 1 week, 40° F (4.4° C) was unacceptable for maintaining fresh onion quality and condition. At 40° and 85 to 95 percent relative humidity, the general appearance of green onions was good on removal after 1 week and very good after trimming following removal. Green onions stored 2 weeks at 40° were only fair in appearance. At 32°, comparable onions were good after 4 weeks' storage and excellent after trimming.

During 4 weeks' storage at 32° F in polyethylene-lined wood crates or in water-resistant, waxed corrugated cartons, green onions were benefited sometimes by applying top ice over the crates or cartons. During holding tests following 1 to 4 weeks' storage in crates at 32°, trimmed, bunched onions remained acceptable for 1 day at 70° (21.1°) or 3 days at 50° (10°). When returned to 32° after trimming, bunching, and film wrapping, onions from 1, 2, 3, and 4 weeks' storage at 32° remained acceptable at 32° for an additional 10 to 14 days. Applying top ice to these film-wrapped onions increased shelf life at 32°.

At 32° F, green onions in perforated polyethylene consumer bags or in waxed cartons kept much better when stored in controlled atmospheres (CA) of 1 percent oxygen (O_2) with 5 percent carbon dioxide (CO_2) or 5 percent O_2 with 15 percent CO_2 than in flowing air. Green onions in flowing CA were also better than onions stored with top and package ice in still air in either polyethylene bags or nonwrapped in waxed cartons. Onions in perforated polyethylene bags in 1–5 CA or 5–15 CA atmospheres were fresh and of good quality after 4 to 8 weeks' storage at 32° and after an additional week at 32° outside the chambers. After 32° storage in CA and 1 day's holding at 70°, all the onions were salable. None of the bunched onions stored in air were acceptable or salable after 4 to 8 weeks at 32° plus 1 day at 70°.

Green onions kept about as well at 32° F in 100 percent nitrogen as in 1–5 CA. Onions stored at 32° in nitrogen and other CA storage atmospheres generally did not curve geotropically as did those in air.

In preliminary tests the length of onions held 4 days in air at 70° F increased 54 percent, whereas at 32° practically no elongation was noted. Only onions held in a horizontal position curved geotropically during elongation.

Fresh life of green onions has been reported to be a few days at 32° F. This was extended at 32° to 4 weeks in air storage, 8 weeks in controlled atmosphere storage under film-wrap protection, and (with some trimming required on removal) for 10 to 12 weeks in controlled atmosphere storage. Following storage, the onions had remaining a shelf life of 3 to 10 days at 32° or 1 day at 70°.

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